NEW MOSAICS OF EUROPA AND MAPPING OF ENDOGENIC UNITS.

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The new Europa images currently being acquired by the Galileo spacecraft have provided an opportunity to update the Voyager-era classifications of surface features. The Voyager dataset was a valuable starting point for such analysis, and the new Galileo images complement it by adding a broader spectral range (out to the near-IR) and higher spatial resolution (up to 20 m/pixel). Classification of spectral units on the surface of Europa is important for relative age dating of surface features [1,2], but first we must normalize variations due to photometric angles and global exogenic modification pattern(s). Accurate cartography is also important to compare tectonically-controlled units with global-scale stress patterns. We are reporting progress in digital cartography and mosaicking of Galileo and Voyager images of Europa, and describing plans for mapping endogenic units. When combined with geologic interpretations, the endogenic unit map should help provide a new understanding of the geologic history of Europa.

Previous work [3,4,5] attempted to find global spectral units for comparison with geologic maps of the time. The dataset available from Voyager 1 and 2 included over 200 narrow-angle camera images of Europa, in five color filters (orange, green, blue, violet, and UV) ranging in wavelength from 0.59 microns to 0.35 microns. Most of the surface was imaged at resolutions of 23 km/pixel or better, at low phase angles (from 3 to 32 degrees). Approximately 20% of the surface was also imaged at relatively high resolution, by Voyager II. These images, in 4 colors, are at a resolution of 2 km/pixel and at high phase angles (86 - 92 degrees).

In order to compare images taken at different phase angles and viewing geometries, various corrections must be made to normalize the images. The original photometric correction [6] incorporated a Minnaert coefficient of 0.5, which was insufficient, especially in the polar regions [4]. An improved photometric function for Europa included limb-darkening corrections which vary with phase angle [3], and later versions used a modified Hapke function [7]. Once the images had their brightness variations due to differences in sun angle and viewing geometry normalized, the hemispheric asymmetry in brightness between the leading and trailing sides became more apparent.

The hemispheric color/albedo asymmetry is most prominent in the UV/violet ratio images, and appears darkest in the center of the trailing hemisphere, decreasing in a cosine pattern to a minimum in the center of the leading hemisphere [6,4]. This distinctive pattern strongly suggests an exogenic origin, confirming previous ideas [8,9]. Nelson *et al* [4] identified three major populations of particles which impact the surface of Europa: (1) micrometeorites whose concentration varies as the cosine of the angle from the center of the leading hemisphere, decreasing to a minimum at the center of the trailing hemisphere [10]; (2) slow magnetospheric plasma ions, which corotate and thus will preferentially impact the trailing hemisphere, again with a cosine distribution which varies from a maximum intensity at the center of the trailing hemisphere to zero at the limb; and (3) fast ions, which have either an isotropic or latitude-dependent pattern, and so cannot explain the hemispheric asymmetry [11].

McEwen [3] noted that the best fit to the exogenic pattern is in fact a second order cosine, which may reflect two superimposed exogenic processes. The exogenic pattern is continuous, suggesting an equilibrium between micrometeorite impacts on the leading hemisphere and magnetospheric sulfur ion implantation on the trailing hemisphere. The observed pattern is likely due to hemispheric variations in grain size as well as composition, both of which are affected by the two processes. The interaction of impact gardening, sublimation, and sputtering erosion on the surface may result in larger grains on the trailing hemisphere [12], although later studies suggesing a globally-uniform surface texture contradict this [7]. Compositionally, there are different color trends in the two hemispheres, with the trailing hemisphere being consistent with UV absorptions by sulfur, SO, and/or SO_2 [13], while the leading hemisphere color trend is consistent with Fe^{3+} impurities due to either endogenic variations or meteoritic material [14]. These two interacting processes may explain the second-order cosine shape of the exogenic pattern [3]; later studies [15] also reported evidence for two spectral effects.

After removing the photometric function and normalizing the exogenic hemispheric variation, the global dataset can then be divided into spectral units. McEwen [3] identified four distinct spectral regions, and on comparison with the high-resolution data inferred that there may be in fact only two distinct

EUROPA MOSAICS AND ENDOGENIC UNIT MAPPING: C.B. Phillips *et al*

spectral endmembers, with the other two categories being mixtures of the two endmembers. Thus, he concluded that Europa's spectral reflectivity, at visible wavelengths, can be classified as a continuous second-order-cosine exogenic pattern, coupled with two distinct endogenic units, one which corresponds to the bright plains and another due to the lineaments and patches of darker and redder material.

While the Voyager-era analyses were able to take advantage of good global coverage, they were hampered by low resolution and a narrow spectral range. The new dataset currently being acquired by the Galileo spacecraft is a good complement to this previous archive, for while its total data return is limited in terms of number of images, it improves significantly on the Voyager data in spectral range (SSI data goes out to 1 micron, NIMS even further into the IR), resolution (our current highest-resolution clear-filter images are 20 m/pixel, as opposed to the Voyager 2 km/pixel), and image quality (the images are better calibrated than Voyager, and suffer far fewer camera distortions and other artifacts). New computer techniques are also available for image processing and analysis. The Voyager dataset is still a valuable asset, however, for it provides global coverage (which we will not repeat with Galileo's nominal mission) as well as images in shorter wavelengths such as UV (the shortest SSI wavelength is 0.41 microns).

To facilitate scientific analysis, we plan to produce the best possible global dataset for Europa, relying on combined Voyager and Galileo data in clear and colored filters. So far, we have produced global merged single-band mosaics which combine medium-resolution (2-6 km/pixel) Voyager and Galileo data, where available, and include lower-resolution Voyager data to fill in the gaps. Most of these holes should be covered with medium-resolution single-filter data by the end of Galileo's nominal mission. We are currently producing a recalibrated Voyager highest-resolution (2 km/pixel) 4-band mosaic, using new computer processing and filtering techniques to improve on the previous work done with these images. We also plan to reexamine the work done in modeling the photometric function of Europa, and the exogenic surface pattern, in the context of the newly-available Galileo wavelengths as well as another decade of ground-based observations.

As mentioned by a number of authors [3,16,17], the appearance of surface features is strongly correlated with phase angle, wavelength, and viewing geometry. Observations made from Voyager images showed an apparent increase in contrast between bright and dark materials with increasing phase angle [3], and dark bands seemed to change to bright topographic ridges as they approached the terminator [18,16]. This was verified by Phillips and McEwen [17] in a comparison of Voyager and Galileo images of the same area at similar resolutions and different phase angles. This study was originally a search for evidence of geologic activity in the 20 years since Voyager, the result of which was that no evidence was found for geologic changes on a scale of 1 km or higher in the small initial region of overlap between Galileo and Voyager data at comparable resolution. Some interesting changes were noted, but all could be attributed to differences in color and viewing geometry.

It is clear that color and spectral behavior have an important effect on the appearance of features on the surface of Europa. Understanding this behavior is necessary for compositional analysis, geologic mapping and classification of features, and relative age dating. As described by Geissler *et al* [1], distinct spectral units of the surface may represent different exposure ages of surface material, which could have important implications for the geologic history of Europa, and by extension the other Galilean satellites. It is our hope that a careful analysis of the merged Galileo-Voyager dataset for Europa will result in an improved understanding of this important problem.

In this poster we will present our latest Europa mosaics, attempts at photometric and exogenic normalizations and classification of endogenic units, and discussion of geologic interpretations.

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